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Barefoot Running: Effects on EMG Activity of Gluteus Medius and Tensor Fascia Latae in Habitually Shod Runners

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This Scholarly Project, submitted by Bailey Neubauer, Zach Drevlow, and Alexandra Gerlach, in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been the reviewed by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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PERMISSION

Title: Barefoot Running: Effects on EMG Activity of Gluteus Medius and Tensor Fascia Latae in Habitually Shod Runners.

Department: Physical Therapy

Degree: Doctor of Physical Therapy

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Acknowledgments

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Abstract

Purpose/Hypothesis: Running has been a common practice in humans since the species' dawn. Due to its relative ease and low cost, running continues to be one of the most popular forms of exercise today. Although running provides many benefits such as disease prevention, injury prevalence in running is high. The trend of minimalist shoes and barefoot training has gained popularity over the decade as a return to a more natural form of running. Some researchers hypothesize that barefoot running can reduce injury rate by changing the biomechanics of the runner. In this study we propose a different hypothesis: barefoot running changes activity of musculature of the hip, increasing activation in muscles that are commonly weak in injured runners. Research investigating the hip muscle activity and movement with barefoot running is lacking in literature; thus, giving rise to the purpose of this study. This multifactorial study was performed to explore the effect of barefoot running on the muscular activity of the gluteus medius (GM) and tensor fascia latae (TFL). The hypothesis being tested was that barefoot running would increase the muscle activity of GM and decrease the muscle activity of TFL.

Materials/Methods: Twenty-six subjects, 20 females and 6 males, with a mean age of 22.8 completed the electromyography (EMG) analyses. EMG muscle activity of TFL and GM was recorded during a maximal isometric contraction, a barefoot running and walking trial and a shod running and walking trial.

Results: There was a significant difference in change of EMG activity were noted when comparing R TFL running shod vs. R TFL running barefoot ($p<0.05$). There was no other significant data when comparing barefoot running, shod running, GM or TFL activity.

Conclusions: Even though there was no statistical significance in the electrical activity of bilateral GM and the L TFL, the mean average of the peak muscle contractions was greater during barefoot running vs. shod running. Further research is recommended to explore the impact of a barefoot training protocol on GM and TFL muscle activity.

Clinical Relevance: This study provides insight to the muscle activity occurring at the hip when foot attire is altered during training. No statistically significant change was found between barefoot or shod groups. This lack of statistical significance may have been due to lack of statistical power, as the number of subjects was low. This may have also been attributed to the imprecise data received for initial contact. While there were no statistically significant findings, trends in the data pointed towards a greater change in GM and TFL activity for the barefoot group. Replicating the study with a higher number of subjects may yield significant results in future research.

Chapter I

Introduction

Endurance running has been inherent to the human experience from the species' dawn. Many anthropologists and scientists hypothesize that early Hominins used their endurance running prowess to pursue their prey, chasing animals until they were to collapse in exhaustion.[1,2] Olympians to hobby joggers today, all benefit from the evolutionary adaptations that have taken place to make *Homo sapiens* an efficient endurance running machine. As running and jogging participation increases in America, with 35.5 million participants in 2010, so does the incidence of injury.[3] There is some variability in injury rate of runners across studies, but all indicate that injuries in the running population are relatively common. A systematic review by Van Gent et al analyzed 17 studies and found the overall incidence of reported lower extremity injuries was as high as 79%. The most commonly injured joint was the knee, with an injury rate of 7.2-50%.[4] Francis et al analyzed 11 studies and found that the knee (28%), ankle-foot (26%), and shank (16%) accounted for the highest proportion of injuries in male and female runners. Female runners had a higher proportion of knee injuries when compared to male runners (40% to 31%), while male runners had a higher proportion of ankle-foot injuries (26%-19%) and shank injuries (21% to 16%).[5] A meta-analysis by Videbæk et al reported that the injury rate per 1000 hours of running was 17.8 for novice runners and 7.7 for recreational runners.[6] This statistic would indicate that if a novice runner ran 30 minutes a day for a year they would incur, on average, over three injuries during that time. The current trend of minimalist shoes is a response to this common occurrence of injury, as runners seek to utilize the natural anatomy of the foot instead of the foam and plastic found in the conventional running shoe.

Minimalist footwear was defined by a group of forty-two experts, mainly consisting of scientists and researchers, as “footwear providing minimal interference with the natural movement of the foot due to its high flexibility, low heel to toe drop, weight and stack height, and absence of motion control and stability devices.”[7] Minimalist footwear can have an effect of the way a runner makes initial contact with the ground while running. Foot strike patterns are commonly divided into three different categories, the hindfoot or rearfoot (talus and calcaneus), midfoot (navicular, cuboid and cuneiforms) and forefoot (metatarsals and phalanges).[8] The features of a minimalist shoe allow the runner to utilize a forefoot strike more easily, as runners wearing conventional running shoes commonly perform a rearfoot strike pattern.[9]

Many studies have found that habitually shod runners with rearfoot strikes transition to a forefoot/midfoot strike when running barefoot.[10,11,12,13] When running with a forefoot/midfoot strike pattern, the body absorbs the ground reaction forces with eccentric control after initial contact.[14] One study also found a reduction in peak impact magnitudes of ground reaction forces in shod rearfoot strikers when switching to barefoot running.[15] These biomechanical variations associated with a forefoot strike may also affect injury rate. A study involving 52 collegiate runners found the rate of repetitive stress injuries to be twice as high in the athletes with a rearfoot strike than a forefoot strike.[13] The authors hypothesize that one of the primary reasons for the relationship between strike pattern and injury rates is the reduction of peak ground reaction force when utilizing forefoot strike rather than rearfoot strike. However, what if there were other mechanisms, relating to muscle activity, which could account for this reduction in injury rate?

Due to a smaller base of support, greater kinematic changes must be made proximally up the chain to stabilize the body against gravity when the foot strikes the ground with the forefoot rather than rearfoot. For example, the gluteus medius acts as a stabilizer at foot strike, preventing the knee from moving into genu valgum.[16] A study involving thirty runners with overuse injuries and thirty runners without injuries, revealed that hip abductor and hip flexors were significantly weaker in the injured group in comparison to the non-injured control group.[17] Not only do hip abductors such as gluteus medius act to prevent ipsilateral genu valgum, they also help stabilize the pelvis to reduce contralateral pelvic drop.[9] Gluteus medius is a key muscle in stabilization of the lower extremity during gait. If the lower extremities can become more stable during gait, a more biomechanically desirable stride will be found. As the gait becomes more biomechanically efficient, it will allow for ideal joint kinematics and a corresponding reduction in injury rate.

Injuries to endurance runners will never be eliminated, however there is room for improvement regarding injury rate with hip abductor weakness possibly predisposing individuals to injury. If utilizing an altered foot strike during barefoot training corresponds with an increased activity of hip abductors, barefoot running may be a useful rehabilitation method. Runners would be able to reduce their risk of injury, while performing their main objective: running. The purpose of the study is to investigate potential differences in gluteus medius and tensor fascia latae through EMG activity while walking and running in a barefoot and shod manner.

Chapter II

Literature Review

Biomechanics

Running shoes have evolved and progressed over the last century. Shoes formerly consisted of a flat sole with a leather top. Now, they often consist of an elevated heel, arch support, and various levels of heel cushioning. These changes to footwear have been shown to change the way humans run when compared to barefoot running. Foot-strike, cadence, joint movements, ground reaction forces, joint forces and proprioceptive input are a few of the factors that are different when comparing the biomechanics of running in modern day footwear to barefoot running.[18] A study by Kelly et al[19] found runners displayed substantially less arch compression and recoil when running with shoes, when compared with barefoot, which supports the key design feature of running shoes that aim to provide support for the longitudinal arch of the foot and reduce strain on plantar soft tissue structures. Recent critiques of modern running footwear have argued that cushioning and support characteristics of the shoe potentially impair foot-spring function, with a likely consequence of reduced activation from muscles that support the arch, leading to their weakness and disuse atrophy.

Kinematics

Strike patterns during the shod running cycle can be classified under two main categories and a third, less common, category: rear-foot strike (RFS), mid-foot strike

(MFS), and fore-foot strike (FFS). During shod running: 75% of runners exhibit a RFS pattern, 20% a MFS, and 5% a FFS.[20] Changing between shod and barefoot running can have a variety of kinematic changes on the body. FFS and MFS runners have been shown to decrease their stride length when switching to barefoot from shod running. In comparison, rear-foot strikers also decreased stride length, in addition to demonstrating a plantarflexed foot position at contact when changing to

barefoot running.[21] These changes are best seen when comparing stride length and cadence. Stride length and cadence are closely associated. Therefore, cadence increases with immediate transition from shod running to barefoot running with relation to decreased stride length. Larger changes in the foot strike pattern during this transition from shod to barefoot running is associated with higher instability which arises in the stance phase and push-off phase; the decreased stability might affect injury risk and performance.[22]

Hip kinematics are affected when shod runners switch to barefoot running. Decreased hip adduction, hip internal rotation, and contralateral pelvic drop was shown with immediate change to barefoot running.[23] Biomechanical changes potentially during stance and push-off phases have also been identified to contribute to increased instability.[23,24] A study done by Paquette et al[25] found that barefoot/ minimalist shoes were often associated with a FFS. This study also found that barefoot/minimalist shoes increased eccentric ankle plantarflexion involvement and decreased eccentric knee extensor involvement. While these studies identified immediate changes. There exists a need to identify the effect barefoot training has on running kinematics.

Kinetics

A difference in ground reaction force has been identified between shod and barefoot running. Shod running is associated with increased ground reaction force and peak magnitude when compared with barefoot running.[26] In addition to decreased ground reaction forces, patellofemoral joint stress and patellofemoral joint reaction forces were measured to decrease by 12% when shod running was compared to barefoot running.[27] A similar result was found in a 2014 study that identified significantly reduced patellofemoral contact force in barefoot running compared to shod. However, they did note that Achilles tendon loading significantly increased in barefoot running.[28] The Achilles tendon may be acting as a "shock absorber" individuals run with a FFS. This could explain the decreased patellofemoral and ground reaction forces that coincide with increased Achilles tendon loading.

Gluteus Medius Function

In 2013, over 50 million Americans participated in running or jogging, a rise of 5% since the previous year. Although the benefits of physical activity are well documented, musculoskeletal injuries are common in runners of all levels.[29] Electromyography (EMG) studies have often been used to assess muscle function during the running and gait cycle in habitual shod runners. In a study of 30 healthy patients, peak forces produced by the gluteus medius during shod running was substantially greater than several other hip muscles, which included biceps femoris, semimembranosus, semitendinosus, gluteus maximus, gluteus minimus, TFL, rectus femoris, sartorius, psoas, illiacus, adductor magnus, adductor brevis, adductor longus, and piriformis.[30] In addition, a review performed by Semciw[29] determined a burst of gluteus medius monophasic EMG activity during the loading phase in the first 5-10% of the gait cycle. Although, research identifies identified significant increase in gluteus medius peak force during shod running, few studies have compared shod running gluteus medius EMG activity to that of barefoot running.

Secondary to the growing popularity of barefoot running, studies have begun to compare the relationship of injuries, biomechanics, and hip muscle activity in barefoot and shod runners. Tam et al[31], found in 26 individuals completing an 8-week progressive barefoot running program, posterior hip activity (gluteus medius and biceps femoris) increased in pre-activity which may indicate a muscle tuning response that increases muscle tension and stabilization for both knee and hip joints during ground contact. Thus, attenuating the initial loading rate by preparing the joint during swing and tuning the muscle for ground contact.[31] The following section discusses research which highlights the prevalence, muscle activity, and potential intervention of common lower extremity running injuries.

Gluteus Medius and Injury

Patellofemoral Pain Syndrome

Patellofemoral pain is an idiopathic condition characterized by aching pain in the peripatellar area which can be exacerbated by physical activity, including running. Patellofemoral pain is the most common musculoskeletal overuse injury in physically active individuals regardless of sex or age.[32] Patellofemoral pain accounts for one of the highest reported injuries among male and female runners (17%).[5]

Patellofemoral pain continues to be an issue in competitive and recreational athletes. Possible treatment for patellofemoral pain syndrome was explored by Bonacci et al[33], in 22 trained runners utilizing both neutral running shoes and barefoot training. Running barefoot decreased peak patellofemoral joint stress by 12% in comparison to shod running.[33] Barton et al[34] found, moderate to strong evidence indicates gluteus medius muscle activity is delayed and shorter during both functional stair activities, as well as running in individuals with patellofemoral pain syndrome. Therefore, increasing in gluteus medius and tensor fascia latae activity to better control femur and pelvic motion may be significant factors during the rehabilitation and prevention of patellofemoral pain.

Low Back Pain

The prevalence of chronic low back pain among recreational runners has been reported as high as 13.6% in the United States.[35] In a study estimating the Global Burden of Disease, low back pain ranked highest in terms of years lived with disability and sixth in overall burden.[36] These numbers are alarming and have led to recent research to address interventions for running patients suffering from low back impairments.

Treating low back pain can be difficult to address in runners. Cai et al[37] examined recreational runners and found those who participated in lower limb exercises, including hip and knee strengthening, had greater improvement in self-rated running capability, knee extension strength, greater increase in running step length, and similar reduction in running induced pain and improvement in back muscle function in comparison to lumbar extension and lumbar stabilization exercises. A four-week study investigated a change in lumbar positioning of 17 participants who transitioned from habitually shod running (10-50 km/week) to barefoot running. Significant differences were found in mean lumbar posture during stance phase with increased lumbar extension when transitioning to barefoot running. Furthermore, a significant reduction in muscle activity of the contralateral lumbar paraspinals was recorded. This observed reduction in contralateral muscle activation in a more upright position may lead to reduction in impact shock after training.[38] Although adequate activation during running is needed to support the spine and create coordination between the trunk and pelvis, excessive lumbar paraspinal activity may be a sign of dysfunction. Van der Hulst et al[39] examined patients with chronic low back pain in which he found increased lumbar muscle activity during all periods of stride, suggesting difficulties with total muscle relaxation.[38,39] These discoveries could lead to a continued change in thinking for rehabilitation of patients suffering from low back pain to a minimalist or barefoot running protocol.

Achilles Tendinopathy

Achilles tendinopathy is a term used by a combination of pain, swelling, and impaired performance of the Achilles tendon.[18] Individuals with Achilles tendinopathy have been shown to have changes in ankle and hip motions. These motions include increased ankle eversion, time to maximum pronation, calcaneal pronation, calcaneal inversion, and decreased hip flexion in the pre-swing phase of gait. Individuals with Achilles tendinopathy were reported to have reductions in gluteus medius onset and activity.[40] Further verification of these results could play vital roles in prevention and rehabilitation in runners, recreational and competitive, suffering from Achilles tendinopathy.

Osteoarthritis

Osteoarthritis (OA) is the most common form of arthritis, involving inflammation and structural changes of the joint, causing pain and functional disability for many. In a systematic review measuring the global burden of 291 conditions, hip and knee osteoarthritis was ranked 11th highest in global disability.[41] Evidence-based clinical guidelines identified by Cibulka et al, state hip abduction strength (specifically gluteus medius) and motor control are physical impairments which need to be addressed with treatment in patients with the presence of hip osteoarthritis.[42] The gluteus medius has been linked as a factor in patients with hip osteoarthritis. Continued function in the presence of neuromuscular alterations may hasten the progression of joint disease and result alternate patterns in functional movements. Furthermore, Dwyer et al,[44] explored muscle activity of the gluteus medius in patients completing functional activities with unilateral, end-stage osteoarthritis of the hip joint scheduled for a total joint replacement compared to healthy individuals. Dwyer et al[43] found increased sEMG activity in patients with end-stage OA compared to healthy patients. This increase in sEMG activity may be a compensatory response to muscle weakness. Patients with insufficient GM strength may require increased central nervous system input to the muscle to maintain proper pelvic position in stance, thus resulting in higher sEMG activity.[44] A 2019 study by Zacharias et al[45] examined peak amplitude, average amplitude, and time to peak of gluteus minimus and medius during a 10m walk, and found similar results to Dwyer et al[43] : altered muscle activity and decreased functional performance in gluteus minimus are demonstrated in participants with hip OA and may be related to radiological severity of OA. In conclusion, interventions including strengthening exercises which target the gluteal muscles should assist in neuromuscular control and result in improved muscular strength not only for individuals with hip OA, but also more broadly in the aging population.

Surface Electromyography (sEMG)

Surface Electromyography (sEMG) is used extensively to measure the electrical activity within skeletal muscles in clinical and research applications. These applications include; investigating neurological diseases, assessment of motor control and muscle dysfunction and the evaluation of rehabilitation/exercise interventions.[46] Normalizing to a reference signal is essential when analyzing and comparing sEMG signals across individuals or trials.[47] While capturing data through sEMG, it is imperative to realize the electrical activity identified is from the examined muscle rather than a representation of strength or muscle force. SEMG recordings provide a safe, easy, and noninvasive method that allows objective quantification of the energy of the muscle. In a study conducted by Bussey et al, day to day reliability was deemed to have a high (.7-.89) to very high (>.90) Intraclass Correlation Coefficient for gluteus medius and biceps femoris muscles when measuring maximum voluntary contraction and sub-maximal volumetric contraction, .84-.98 and .73-.95, respectively.[48] Experience between examiners plays a role in intra- and inter-session reliability in placement and execution of pre-recording procedures. The muscles under consideration in this study via sEMG will be gluteus medius and tensor fascia latae. Due to interference, which may lead to unreliable data, this study will be conducted utilizing wireless EMG to increase reliability and allow subjects to normalize their running style. SEMG reliability and validity for gluteus medius or tensor fascia latae during shod or barefoot running was not considered in this literature.

Tensor Fascia Latae and Iliotibial Tract

The tensor fascia latae (TFL) muscles lies along the lateral portion of the iliac crest. Hip flexion, abduction, and medial rotation are the three actions performed by the TFL. It inserts into the iliotibial band (ITB), a fascial structure running from the hip to the knee. The ITB has been scrutinized as a potential source of pain and injury in runners. Author's suggested increased hip adduction and knee internal rotation during prolonged running may be associated with the development of ITB syndrome.[49] Research has shown barefoot running may decrease hip adduction during running therefore, this may also assist in injury prevention for ITB syndrome.[49] ITB friction syndrome is often attributed to lateral knee pain in runners. A recent study identified the ITB as a source of elastic energy storage during running. The ITB can store roughly 1 Joule of energy during jogging and 7 J of energy during fast running.[50] The TFL has a direct influence on this energy transfer due to its insertion into the ITB. Therefore, altering mechanics and TFL activation during barefoot running may contribute to decreased incidence of ITB friction syndrome.

Chapter III

Methods

Outlined below are the methods used in the study. These include patient selection criteria and EMG data collection.

Participant Selection

Participants were recruited via an in-class presentation outlining the study. Study details were shared with the University of North Dakota first- and second-year physical therapy students. Inclusion criteria and study information was distributed through email communication. To participate, individuals must be (1) a rearfoot striker, (2) currently complete between 0-20 miles of running per week, (3) age 20-30 (4) habitually shod runner. Those with (1) a significant injury to the lower extremity in the past 6 months, (2) use of NSAIDS, (3) cardiopulmonary pathologies or significant medical history, or (4) forefoot strikers were excluded.

EMG

Procedure

All participants completed an informed consent. Participants identified foot dominance and agreed to have height and weight measured with BMI calculated. Each participant was randomly assigned to starting either shod or barefoot walking. Participants completed a minimum of 20 seconds of barefoot and shod walking and running. In the following section, electrode placement for the gluteus medius and tensor fascia latae will be described, in addition to MVC process and data collection.

Electrode Placement

Each electrode placement was prepared by berating the skin with sandpaper for a total of three times. Each area was then cleansed with rubbing alcohol. Once electrodes were placed over each muscle, electrical impedance was measured using the NORAXON Electrode Impedance Meter. If the electrode impedance was greater than 10k, the electrode was removed, and the procedure was repeated. Foot contact sensors were applied to each of the participant's right foot. Sensors were placed on the first metatarsal head and the calcaneus, to identify timing of muscular activity with ground contact. This allows for clear distinction between stance and swing phases of the participants gait pattern. The leads were placed as follows (Figure 1):

- Lead One: Left Gluteus Medius
- Lead Two: Right Gluteus Medius
- Lead Three: Left Tensor Fascia Latae
- Lead Four: Right Tensor Fascia Latae

Gluteus Medius

The most superior point of the greater trochanter and most superior point of the iliac crest were identified through palpation and the distance between each point was measured in centimeters. A point was marked one-third the total distance beginning from the most cranial point of the iliac crest.[48] An electrode was placed above and below the mark so that they were spaced two centimeters apart. The electrodes were placed so that they ran parallel with the muscle fibers of gluteus medius. The same process was completed on the contralateral side of the patient.

Tensor Fascia Latae

The most caudal point of the anterior superior iliac spine was located by palpation technique and a mark was placed two centimeters distally.[48] Two electrodes were placed over the mark, so the center of each electrode was two centimeters apart at each tensor fascia latae.[43] The electrodes were placed so that they ran parallel with the muscle fibers of the tensor fascia latae. This process was completed bilaterally.

(A)

(B)

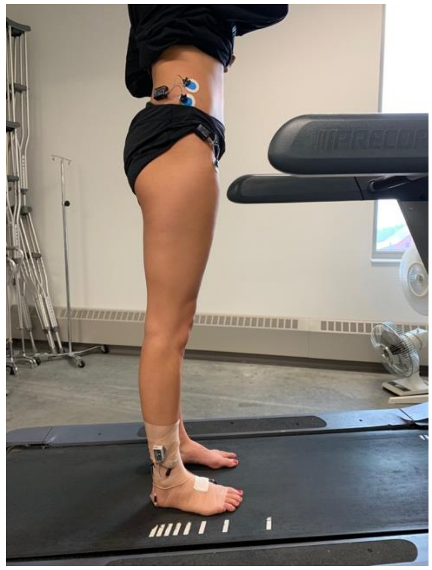

Figure 1 – Electrode Placement - (A) Shod, (B) Barefoot

Maximum Voluntary Contraction

Following electrode placement, participants completed bilateral gluteus medius and tensor fascia latae maximum voluntary contractions (MVC). To determine the participants MVC of the gluteus medius, participants were positioned side-lying, and, with a goniometer, measured into thirty degrees of hip abduction, neutral hip rotation, and zero degrees of hip flexion/extension (Figure 2). Participants were asked to slowly lift their leg until contacting the belt and push maximally for five seconds. Testing of the MVC for the tensor fascia latae included the participant in side-lying, and, with a goniometer, measured into thirty degrees of abduction, neutral hip rotation, and forty-five degrees of hip flexion (Figure 3). Again, participants were asked to slowly lift their leg until contacting the belt and push maximally for five seconds. This process was repeated bilaterally for each muscle.

Figure 2 - Maximal Voluntary Contraction of Gluteus Medius: Subjects were positioned with thirty degrees of hip abduction, neutral hip rotation, and zero degrees of hip flexion/extension.

Figure 3 - Maximal Voluntary Contraction of Tensor Fascia Latae: Subjects were positioned with thirty degrees of hip abduction, neutral hip rotation, and forty-five degrees of hip flexion.

Data Collection

Data were collected while each participant walked on the treadmill at three MPH for 30 seconds then transitioned to running at six MPH for 30 seconds. The first 10 seconds of both the walking and running periods were used for the subjects to normalize their gait, while the final 20 seconds were used for recording EMG activity. The participants then donned or doffed their shoes, depending on their random selection, and repeated the walking and running trials.

Surface EMG electrodes were placed over the GM and TFL bilaterally through the method outlined in the above *Electrode Placement* section. EMG data was collected using an eight channel Noraxon Telemyo 2400 system. The EMG signals were rectified, smoothed (RMS 50) and then normalized to the respective maximal voluntary contraction prior to analysis.

Chapter IV

Results

EMG data was collected to analyze muscle activity for each of the 26 participants during barefoot walking, barefoot running, shod walking and shod running. This data was examined using the Statistical Package for Social Sciences (SPSS). Each data comparison was analyzed utilizing an independent sample t-test to determine clinical significance.

Does barefoot running and walking alter EMG activity in the tensor fascia latae?

Comparing the effect of barefoot versus shod running on the activation of the tensor fascia latae, no statistically significant results were noted between groups in the left TFL, however there were consistent trends towards increased activity with barefoot running and barefoot walking. The right TFL demonstrated significant results in activation during running barefoot (41.41) and running shod (34.86) and a trend towards increased activation in walking barefoot versus walking shod.

Does barefoot training alter EMG activity in the gluteus medius?

There were no significant findings on the effect of barefoot running on EMG activity to the gluteus medius. However, there were consistent trends across all treadmill activities that suggests there could be clinical significance. The mean activation of barefoot running and barefoot walking in comparison in comparison to shod also shows a trend towards increased activation of the right gluteus medius and shows similar results in the left.

Possible causes of these trends in EMG activity are explored in the following discussion section.

Table 1. EMG Activity in R GM Barefoot Running/Walking vs. Shod Running/Walking

	Mean	**SD**
WB R GM	26.852	7.221
RB R GM	56.000	34.910
WS R GM	26.584	7.574
RS R GM	51.700	31.118

*WB=Walking Barefoot, RB=Running Barefoot, WS=Walking Shod, RS=Running Shod

Table 2. EMG Activity in L GM Barefoot Running/Walking vs. Shod Running/Walking

	Mean	**SD**
WB L GM	25.724	8.816
RB L GM	44.652	10.565
WS L GM	25.060	7.858
RS R GM	43.416	12.074

*WB=Walking Barefoot, RB=Running Barefoot, WS=Walking Shod, RS=Running Shod

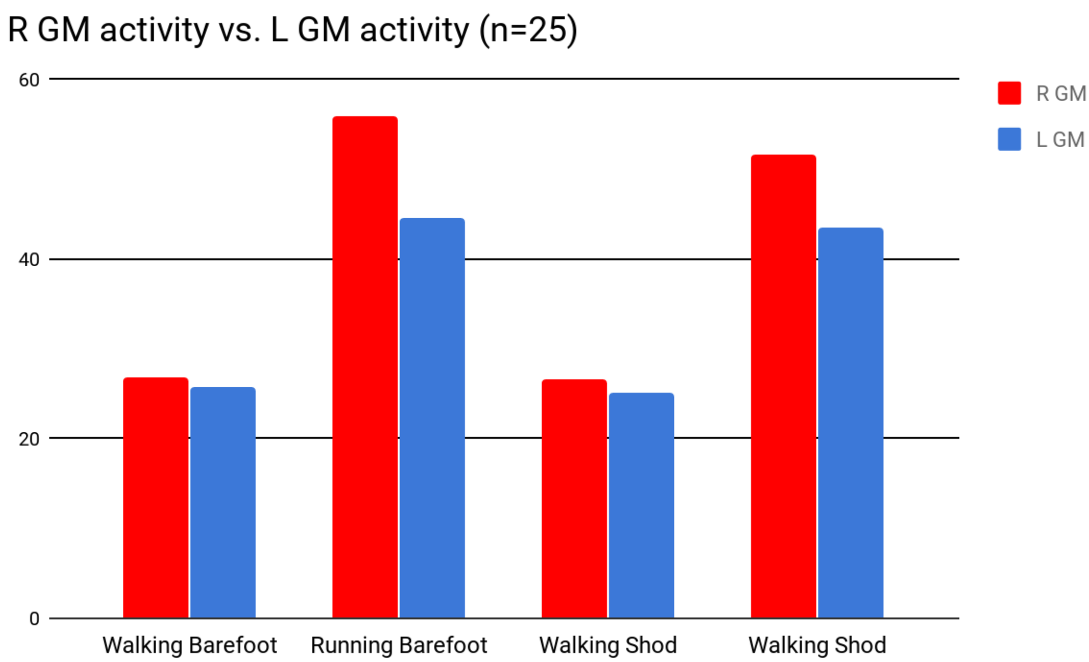

Figure 4. EMG Activity in GM Barefoot Running/Walking vs. Shod Running/Walking

Table 3. EMG Activity in R TFL Barefoot Running/Walking vs. Shod Running/Walking

	Mean	**SD**
WB R TFL	17.024	6.150
RB R TFL	41.408	22.012
WS R TFL	17.140	8.300
RS R TFL	34.864	16.535

*WB=Walking Barefoot, RB=Running Barefoot, WS=Walking Shod, RS=Running Shod

Table 4. EMG Activity in L TFL Barefoot Running/Walking vs. Shod Running/Walking

	Mean	**SD**
WB L TFL	15.512	7.736
RB L TLF	50.232	61.034
WS L TFL	14.970	7.525
RS L TFL	30.828	11.599

*WB=Walking Barefoot, RB=Running Barefoot, WS=Walking Shod, RS=Running Shod

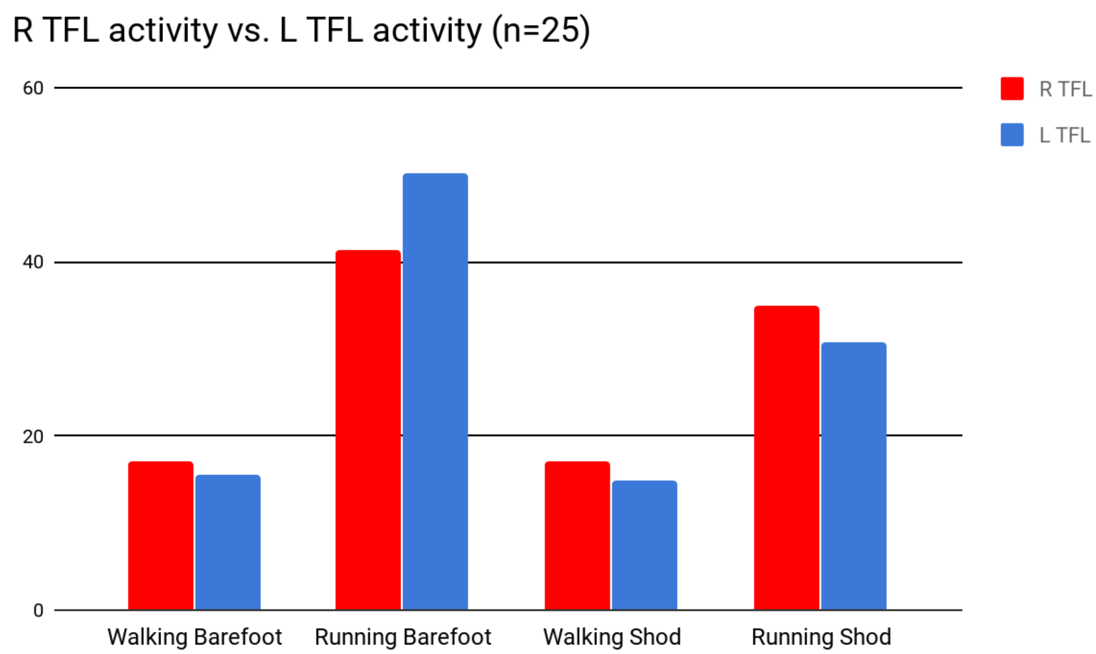

Figure 5. EMG Activity in TFL Barefoot Running/Walking vs. Shod Running/Walking

Table 5. Pairwise Comparisons

	Significance[b]
WB R GM vs. WS R GM	1.000
RB R GM vs. RS R GM	0.190
WB L GM vs. WS L GM	1.000
RB L GM vs. RS L GM	1.000
WB R TFL vs. WS R TFL	1.000
RB R TFL vs. RS R TFL	0.004
WB L TFL vs. WS L TFL	1.000
RB L TFL vs. RS L TFL	0.684

*WB=Walking Barefoot, RB=Running Barefoot, WS=Walking Shod, RS=Running Shod, [b]=95% Confidence Interval

Chapter V

Discussion

Conclusion

This study investigated the effect of barefoot running and EMG activation of gluteus medius and tensor fascia latae. We anticipated seeing an overall increase in activation of these hip muscles during barefoot running. There were statistically significant results regarding increased activation of the right TFL in the barefoot trial when compared to the shod trial. However, there were no statistically significant differences between shod and barefoot groups regarding EMG activation of the gluteus medius and the left TFL muscles. Barefoot running trended towards having an increase in both gluteus medius activation and TFL activation, when compared to shod running. These results may be interpreted as showing shod running to increase TFL activation and decrease gluteus medius activation, whereas barefoot running increased both TFL and gluteus medius activation with a greater degree exhibited with TFL. This may be attributed to a combination of the kinematic changes seen with forefoot and rearfoot striking and the effect of footwear on the human kinetic chain.

Limitations

Limitations affecting this study include equipment limitations and sample size. The EMG data received from the foot switches was not clean, and therefore establishing a manual pinpoint of the footstrike was difficult and may not have been consistent. Lack of statistical significance in the data may be attributed to this fault. The power of this study was limited due to a small sample size (n=26). This limitation can be contributed to participants being physical therapy students which would not allow for a diverse sample.

Clinical Significance

Evidence in the literature review shows hip abductors provide stabilization during gait which may reduce genu valgum therefore reducing the likelihood of impairments such as patellofemoral pain syndrome, hip osteoarthritis, low back pain and Achille's tendinopathy. The trend toward increased muscle activation of bilateral GM and TFL during barefoot running demonstrates clinical significance for muscle strengthening and injury prevention throughout the kinematic chain.

Recommendations for Future Research

Need exists for further randomized controlled trials with systematic methodology to investigate the effects of shod and barefoot running due to the incidence and prevalence of injury with running activities. Specifically, tensor fascia latae in comparison to gluteus medius. The findings examined in our study, although not statistically significant, suggest there is a change in muscular activity favoring increased gluteus medius and tensor fascia latae activity with barefoot running. Furthermore, there are copious amounts of research investigating the level of gluteus medius activity in relation to barefoot running, however there remains a void in regard to the tensor fascia latae and barefoot training.

APPENDIX A: INFORMED CONSENT

INFORMED CONSENT DOCUMENT TEMPLATE: NON-MEDICAL PROJECTS

IC 701-B

THE UNIVERSITY of NORTH DAKOTA
INSTRUCTIONS FOR WRITING AN INFORMED CONSENT DOCUMENT
NON-MEDICAL CONSENT TEMPLATE

INSTRUCTIONS:

- This consent document template is recommended for non-medical studies because it contains all required elements of consent.

- The text in bold throughout this document offers suggestions and guidance. It should be deleted and replaced with information specific to your study. The headers and footers are not meant to be edited and should remain on your consent document.

CONSENT DOCUMENT INSTRUCTIONS:

- Consent documents should be written in the second person (e.g., "You are invited to participate"). Use of the first person (e.g., "I understand that…") can be interpreted as suggestive and can constitute coercive influence over a subject.

- The consent form should be written at about an eighth grade reading level. Clearly define complicated terms and put technical jargon in lay terms.

- The consent form must be signed and dated by the subject or the subject's legally authorized representative. The signed consent from each subject must be retained by the investigator and a copy of the consent form must be provided to the subject.

CONSENT DOCUMENT FORMAT:

- To facilitate the IRB review process, the sample format below is recommended for consent forms.
- Prepare the entire document in 12 point type, with no blank pages or large blank spaces/paragraphs, except for a 2 inch by 2 ½ inch blank space on the bottom of each page of the consent form for the IRB approval stamp.

- Multiple page consent documents should contain page numbers and a place for the subject to initial each page.

ASSISTANCE

- If you have questions about or need assistance with writing an informed consent please call the Institutional Review Board office at 701 777-4279.

THE UNIVERSITY OF NORTH DAKOTA
CONSENT TO PARTICIPATE IN RESEARCH

TITLE: *Barefoot versus Shod Running: Training Effects on Navicular Drop and Foot Pressure Analysis*

PROJECT DIRECTOR: *Gary Schindler*

PHONE # *701-777-6081*

DEPARTMENT: *Physical Therapy*

STATEMENT OF RESEARCH

A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask.

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to be in a research study that is interested in investigating how running and walking barefoot versus shod (shoe) effects navicular and pelvic movements (the amount that the navicular bone drops to the ground with weight bearing activities) and surface Electromyography (EMG) activity of the Tensor Fasciae Latae (TFL) and Gluteus Medius (GM) during waling and running activities. Literature identifies the barefoot runners complete more of a forefoot strike than shod runners (rear foot) which can lead to more gastrocnemius (calf) activation creating more supinated (walking/running more on the outside of the foot) foot mechanics. In addition, literature has not investigated the EMG activity of GM and TFL musculature during barefoot walking and running. This study aims to investigate whether barefoot walking and running versus shod walking and running reduces the amount of navicular drop and surface EMG activity of the TFL muscle while increasing EMG activity of the GM muscle during walking and running activities. You have been identified as a potential participant because you are a first, second, or third-year physical therapy, athletic training, or occupational therapy student at the University of North Dakota, a novice runner (0-20 miles per week), and meet this study's inclusion criterion.

The purpose of this research study is to understand what effect barefoot walking and running has on navicular/pelvic motion and EMG activity of the TFL and GM muscles compared to shod walking and running, which may assist in future injury prevention.

HOW MANY PEOPLE WILL PARTICIPATE?

A minimum of 6 participants will be take part in this study at the University of North Dakota. Each participant will complete a one-time navicular/pelvic movement assessment during walking and running utilizing the VICON motion analysis system and complete a one-time surface EMG of the TFL/GM muscles during shod/barefoot walking and running activities. The Vicon Motion Analysis system utilizes 10 separate cameras in order to obtain a 3D motion analysis image of lever arms and joints. This system will assist in detecting the amount and speed of navicular drop and measure changes in pelvis and knee angles during barefoot walking/running activities between training groups. Testing will take place at the Hyslop Sports Center on the campus of the University of North Dakota

be randomly placed in either the shoe running group or barefoot running group with each group having a minimum of 3 participants. Each group will complete pre- and post-test navicular drop, walking/running analysis utilizing the VICON motion analysis system, and surface EMG of the TFL/GM muscles during shod/barefoot walking and running and complete a post-survey analysis to determine compliance and training schedule. The Vicon Motion Analysis system utilizes 10 separate cameras in order to obtain a 3D motion analysis image of lever arms and joints. This system will assist in detecting the amount and speed of navicular drop and measure changes in pelvis and knee angles during barefoot walking/running activities between training groups. In between the pre- and post-tests each individual will complete a 6-week training schedule involving running on a treadmill with a gradual progression of distance and time per week as symptoms allow. Surveys will be completed at the time of the post-testing at the Hyslop Sports Center on the campus of the University of North Dakota.

HOW LONG WILL I BE IN THIS STUDY?

Your participation in the study will include a one-day testing. Each participant will complete a one-time navicular/pelvic movement assessment during walking/running utilizing the Vicon Motion Analysis system, and surface EMG analysis of the TFL and GM during shod and barefoot walking/running.

WHAT WILL HAPPEN DURING THIS STUDY?

Those who choose to participate will be screened to determine qualification to participate in the study according to the inclusion criteria which includes: no significant injury in the lower extremities in the past 6-months, age between 18-35, greater than 7 mm navicular drop, must be a rear foot striker, no current use of NSAIDs, no cardiopulmonary pathologies or significant medical history, and must currently complete between 0-20 miles of running per week. If you are included in this research, this study will take place over approximately a one-day testing requirement A bilateral navicular drop test, foot/pelvis motion analysis utilizing the Vicon Motion Analysis system, and surface EMG of your TFL and GM musculature will be performed on you during shod/barefoot walking and running. No personal identifications are used on any written document and all descriptions of participants are anonymous.

WHAT ARE THE RISKS OF THE STUDY?

There are no foreseeable risks of physical, emotional, or financial risks to the participants with this study; however, since physical activity is taking place there may be a chance of muscle strains, fatigue, tendinitis, stress fractures, delayed onset muscle soreness (DOMS), or a general pain response, but minimal risk is anticipated. A certified athletic trainer, licensed physical therapist, sports/orthopedic specialist, and certified strength and conditioning specialist will be on site for all training sessions to answer any questions and to direct activity progression to limit adverse reactions. If adverse reactions occur the participant will be evaluated by the primary investigator and will be referred for further medical evaluation if deemed necessary.

WHAT ARE THE BENEFITS OF THIS STUDY?

Each participant may not benefit personally from being in this study. It is possible that the participants may see a decrease in static/dynamic navicular drop, decreased TFL EMG activity, and increased GM EMG activity, which may aid in injury prevention. Participants may also see improved cardiorespiratory fitness and a decrease in BMI. Also, we hope that in the future other people might benefit because a better understanding of how barefoot running and walking may affect navicular placement and movement and alter foot pressure, which may assist in reduced pain, improved function, and prevention of future overuse injuries for some patients. This research may impact how physical therapists practice clinically, therefore impacting the lives of their patients and their families. This research may lead to alterations in exercise training that may lead to less future injuries.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any costs for participating in this research study.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for participating in this research study.

WHO IS FUNDING THE STUDY?

No funding is needed for this study. The University of North Dakota and the research team are receiving no payments from any agencies, organizations, or companies to conduct this research study.

CONFIDENTIALITY

The records of this study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Your study record may be reviewed by Government agencies, the UND Research Development and Compliance office, and the University of North Dakota Institutional Review Board.

Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. You should know, however, that there are some circumstances in which we may have to show your information to other people. For example, the law may require us to show your information to a court or to tell authorities if we believe you have abused a child, or you pose a danger to yourself or someone else. Confidentiality will be maintained with anonymous surveys conducted. All data collections will be kept anonymous by means of a 5-digit code that will include the participant's mother's or father's day of birth and the last three digits of their zip code while in high school. Consent forms will be kept in a locked and secure location for a minimum of three years, with only Gary Schindler having access to the consent forms and personal data.

If we write a report or article about this study, we will describe the study results in a summarized manner so that you cannot be identified.

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota.

If you decide to leave the study early, we ask that you inform Gary Schindler that you would like to withdraw.

CONTACTS AND QUESTIONS?

The researchers conducting this study are Gary Schindler. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Gary Schindler at 701-777-6081 or at gary.schindler@med.und.edu.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at (701) 777-4279 or UND.irb@research.UND.edu.

- You may also call this number about any problems, complaints, or concerns you have about this research study.
- You may also call this number if you cannot reach research staff, or you wish to talk with someone who is independent of the research team.
- General information about being a research subject can be found by clicking "Information for Research Participants" on the web site: http://und.edu/research/resources/human-subjects/research-participants.cfm

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name: ____

_______________________________ ________________

Signature of Subject Date

I have discussed the above points with the subject or, where appropriate, with the subject's legally authorized representative.

_______________________________ ________________

Signature of Person Who Obtained Consent Date

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